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RESEARCH MEMORANDUM

FLIGHT INVESTIGATION OF AN AILERON AND A SPOILER ON A WING

OF THE X-3 AIRPLANE PLAN FORM AT MACH NUMBERS

FROM 0.5 TO 1.6

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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RESEARCH MEMORANDUM

FLIGHT INVESTIGATION OF AN AILERON AND A SPOILER ON A WING OF THE X-3 AIRPLANE PLAN FORM AT MACH NUMBERS FROM 0.5 TO 1.6

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SUMMARY

A flight investigation has been made to determine the rolling effectiveness and drag of several controls on a tapered wing which was unswept at the 75-percent-chord line (X-3 airplane plan form). The investigation was made by the use of rocket-propelled models in free flight over a Mach number range from 0.5 to 1.6. The results indicate that the rolling effectiveness was slightly higher for a 0.25-chord aileron deflected 5° than for a 0.02-chord trailing-edge spoiler, except in the transonic region. In the subsonic range the difference was negligible. At supersonic speeds, the difference in rolling effectiveness was near the limits of experimental accuracy, but because of the consistency of the variation over the supersonic range, it is believed to be significant. Drag coefficient was higher for the wing with spoilers than for the wing with aileron, but the difference is believed to be largely due to a difference in the airfoil sections of the two wings. There was no appreciable difference in either rolling effectiveness or drag coefficient for the spoiler mounted flush with the wing surface and raised 0.01 chord above the wing surface.

INTRODUCTION

An investigation has been made in free flight to determine the rolling effectiveness and drag of two types of controls on a tapered wing which was unswept at the 75-percent-chord line (X-3 airplane plan form). The investigation was made with rocket-propelled models in free flight over a Mach number range from 0.5 to 1.6. The controls tested included a 0.25-chord aileron deflected 5° and a 0.02-chord spoiler, both extending over the outboard 30 percent of the semispan. Tests were made with the spoiler mounted flush with the wing surface and with a 0.01-chord gap between the spoiler and the wing surface. This paper presents the results of the investigation.

SYMBOLS

b	wing span, ft
c	local wing chord, ft
c_l	section lift coefficient
C_D	drag coefficient based on exposed wing area (1.04 sq ft)
G	shear modulus, lb/sq in.
J	torsional constant of free-stream airfoil section, in.^{4}
M	Mach number
p	rolling velocity, rad/sec
R	Reynolds number based on mean exposed wing chord of 0.626 ft
V	model flight-path velocity, ft/sec
$pb/2V$	wing-tip helix angle, rad
α	angle of attack, deg
δ	deflection of each aileron, deg
α_δ	angle of attack of wing-aileron section equivalent to unit aileron deflection, $\dfrac{dc_l/d\delta}{dc_l/d\alpha}$

MODELS AND TESTS

The models tested consisted of two wings on a pointed cylindrical body which was equipped with a tail that was free to roll relative to the body so as to keep the models near zero angle of attack and zero angle of yaw without affecting the rolling effectiveness of the controls. The wings had an aspect ratio of 3.04, a taper ratio of 0.40, a semispan of 1.04 feet, an exposed area of 1.04 square feet, and were unswept at the 75-percent-chord line. The maximum thickness of the airfoil sections was 0.045c. The wing of model 1 had a sharp trailing edge, but, because of the impracticability of mounting a trailing-edge spoiler on a full-scale airplane wing with sharp trailing edge, the basic airfoil section was modified on models 2 and 3 to give a blunt trailing edge 0.02c thick. Model 1 was equipped with a 0.25c sealed flap-type aileron and models 2 and 3 with 0.02c spoilers located at the trailing edge of both wings. On model 2 the spoiler was attached directly to the wing surface, whereas on model 3 the spoiler was raised 0.01c above the wing surface. The aileron deflection (5°) of model 1 was selected so as to make the displacement of the aileron trailing edge from the chord plane approximately equal to the height of the spoilers on models 2 and 3. Both the ailerons and the spoilers extended over the outboard 30 percent of the semispan. All wings were made of solid aluminum alloy. The geometric details and dimensions of the models are given in the photographs of figure 1 and the sketches of figure 2.

The models were propelled to a Mach number of 1.6 by a two-stage rocket propulsion system. All test data were recorded during a period of free flight following burnout of the second propulsion stage. Rolling velocity was measured by special radio equipment (spinsonde) and model flight-path velocity and range coordinates by means of radar. Atmospheric data were recorded immediately before the model flights by radiosonde and were used with the model test data to calculate the variation of the rolling-effectiveness parameter $pb/2V$ and drag coefficient C_D with Mach number. The range of test Reynolds numbers is given in figure 3. A more detailed description of the test technique is presented in references 1 and 2.

ACCURACY

From previous experience and mathematical analysis it is estimated that the test data are accurate within the following limits:

	Subsonic	Supersonic
$pb/2V$	± 0.004	± 0.002
C_D	± 0.004	± 0.002
M	± 0.01	± 0.01

DISCUSSION OF RESULTS

Rolling Effectiveness

Comparison of aileron and spoiler.- The variation of the rolling-effectiveness parameter pb/2V with Mach number is presented in figure 4. Rolling effectiveness was corrected by the method of reference 3 for the small wing-incidence errors resulting from construction tolerances. No correction was made for the effects of moment of inertia in roll, since reference 1 shows this correction to be small. It may be seen from figure 4 that the pb/2V curve for the aileron model is slightly higher than those of the spoiler models except in the transonic region. In the subsonic range, the difference is negligible. At supersonic speeds, the difference in rolling effectiveness is near the limits of experimental accuracy, but because of the consistency of the variation over the supersonic range, it is believed to be significant. It should be noted that the wing trailing edge of the aileron model was sharp whereas the trailing edges of the wings of the spoiler models were blunt. Reference 4 indicates that blunting the trailing edge of the wing increases aileron control effectiveness slightly. If the trailing-edge thickness of the aileron model in the present investigation were increased to that of the spoiler models, the difference in rolling effectiveness for the aileron and the spoiler would probably be greater. There was essentially no difference in the rolling effectiveness of the spoiler when mounted flush with the wing surface and raised 0.01c above the wing surface.

Aeroelastic effects.- The effects of aeroelasticity on the rolling effectiveness of the aileron model are shown in figure 5 by a comparison of the rolling effectiveness of a solid aluminum-alloy wing and a solid magnesium wing with rigid-wing rolling effectiveness. Solid magnesium was selected arbitrarily as a means of extending the range of structural characteristics for which rolling effectiveness is presented. The method of reference 5 was used to obtain the rolling effectiveness of the rigid and magnesium wings and to correct the rolling effectiveness of the aluminum-alloy wing to sea-level conditions. The data of figure 5 are cross-plotted in figure 6 to give the variation of rolling effectiveness with the structural-stiffness parameter c^4/GJ at various Mach numbers. The curves of figure 6 may be used to obtain an estimate of the rolling effectiveness of a wing of the same plan form with any value of c^4/GJ that falls within the range considered. The method of reference 5 is not applicable to spoilers, so the effects of aeroelasticity on spoiler rolling effectiveness were not determined.

Comparison with theory.- Rigid-wing rolling effectiveness is compared with various theoretical calculations in figure 7. Theoretical rolling effectiveness was calculated by using the zero-aspect-ratio theory of reference 6 at subsonic speeds, the linearized three-dimensional theory of reference 7 at supersonic speeds, and the strip theory of reference 3 at both subsonic and supersonic speeds. Good agreement is shown between experiment and both three-dimensional and strip theories at supersonic speeds. Experiment agrees fairly well with strip theory in the subsonic region also, but is underestimated by about 20 percent by zero-aspect-ratio theory. However, it should be noted that in the strip theory and zero-aspect-ratio theory calculations, theoretical values of α_δ were used which are believed to be considerably lower for wings of low aspect ratio at subsonic speeds.

Drag Coefficient

The variation of the drag coefficient C_D with Mach number is presented in figure 8 for all models. The drag coefficient of the body alone equipped with free-rolling tail is included in the figure for reference. The drag coefficient of the wing with spoilers is considerably higher than that of the wing with ailerons except in the transonic region. However, reference 4 shows that blunting the trailing edge of the wing increases drag appreciably. The fact that the spoiler models had blunt trailing edges is believed to account for the larger part of the difference in the drag of the aileron model and spoiler models. There is no appreciable difference in the drag coefficient of the wing with spoiler mounted flush and with spoiler raised 0.01c above the wing surface.

CONCLUSIONS

From the results of a free-flight investigation at essentially zero angle of attack and zero angle of yaw of the rolling effectiveness and drag of an aileron and a spoiler on a tapered wing which was unswept at the 75-percent-chord line (X-3 airplane plan form) the following conclusions may be drawn:

1. The rolling-effectiveness curve for a 25-percent-chord aileron deflected 5° is slightly higher, except in the transonic region, than that of a 2-percent-chord trailing-edge spoiler of the same span. In the subsonic range, the difference is negligible. At supersonic speeds, the difference in rolling effectiveness is near the limits of experimental accuracy but because of the consistency of the variation over the supersonic range, it is believed to be significant. There was essentially no difference in the rolling effectiveness of the spoiler when mounted flush with the wing surface and raised 0.01c above the wing surface.

2. The drag coefficient is higher for the wing with spoilers than for the wing with ailerons except in the transonic region. However, the wing with spoilers had a blunt trailing edge whereas the trailing edge of the wing with ailerons was sharp. This difference in airfoil section is believed to have caused most of the difference in drag. Drag coefficient was essentially the same for the spoiler with bottom edge flush with the wing surface and with bottom edge 0.01 chord above the wing surface.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 16, 1954.

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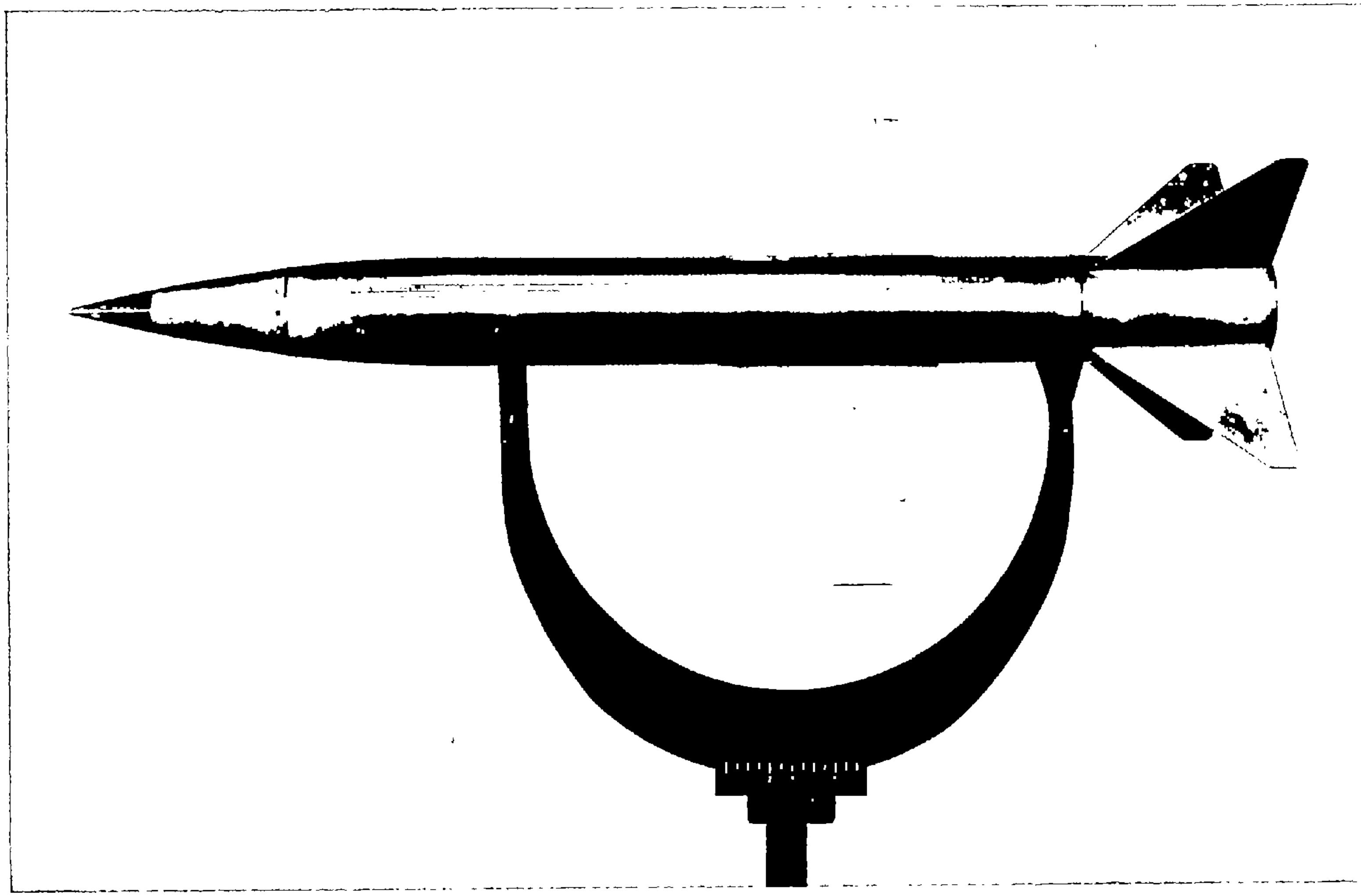

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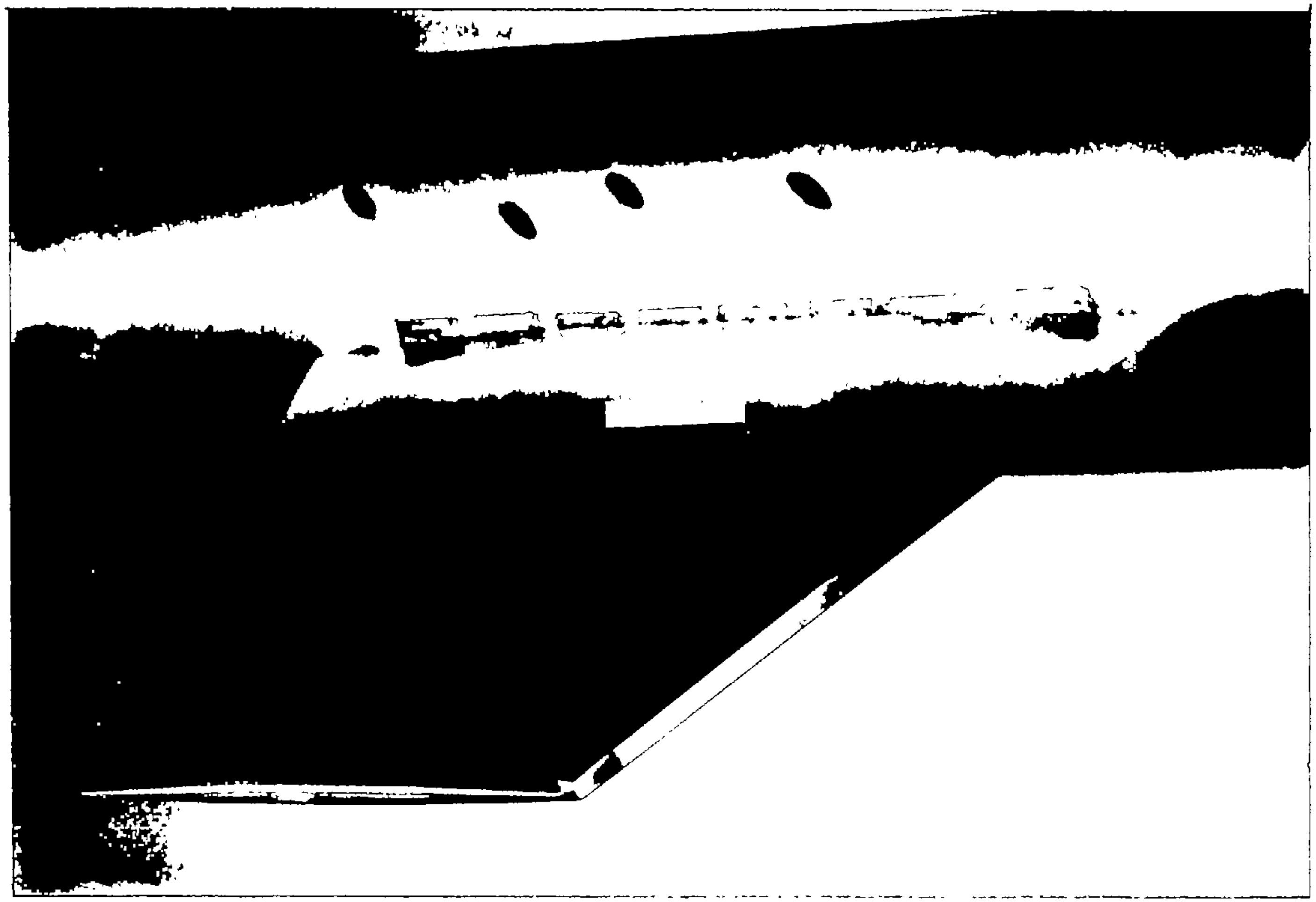
(a) Model 1.

Figure 1.- Photographs of typical models.



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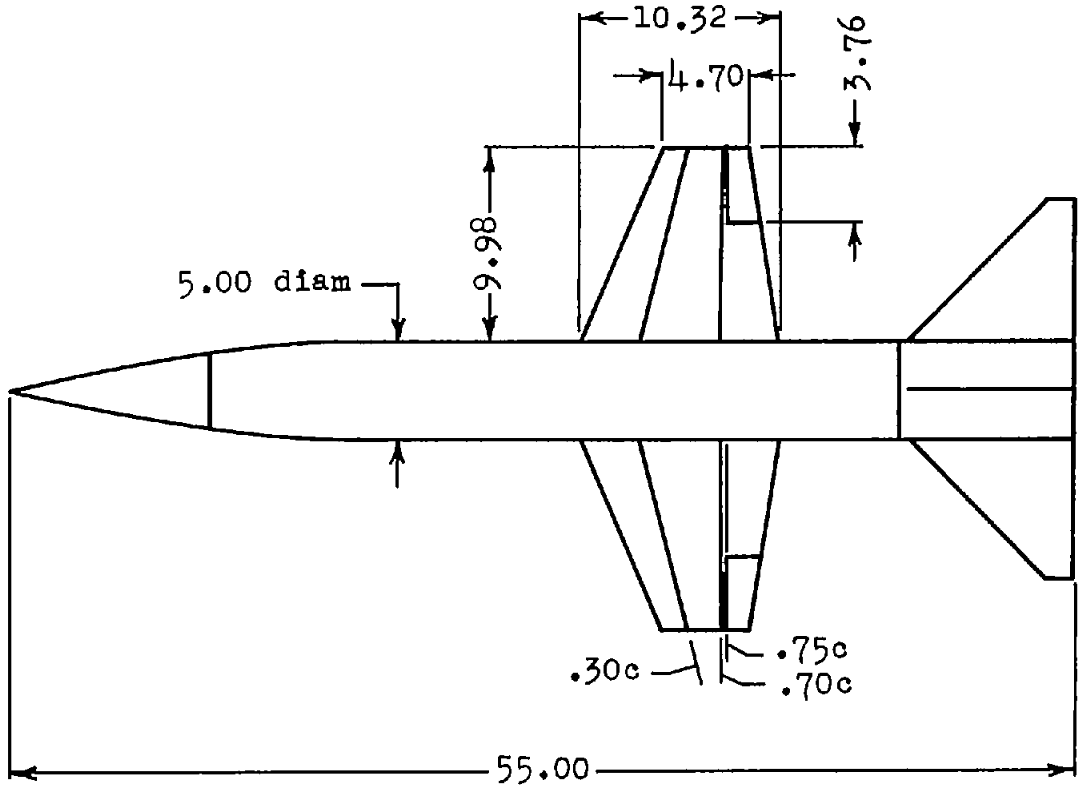
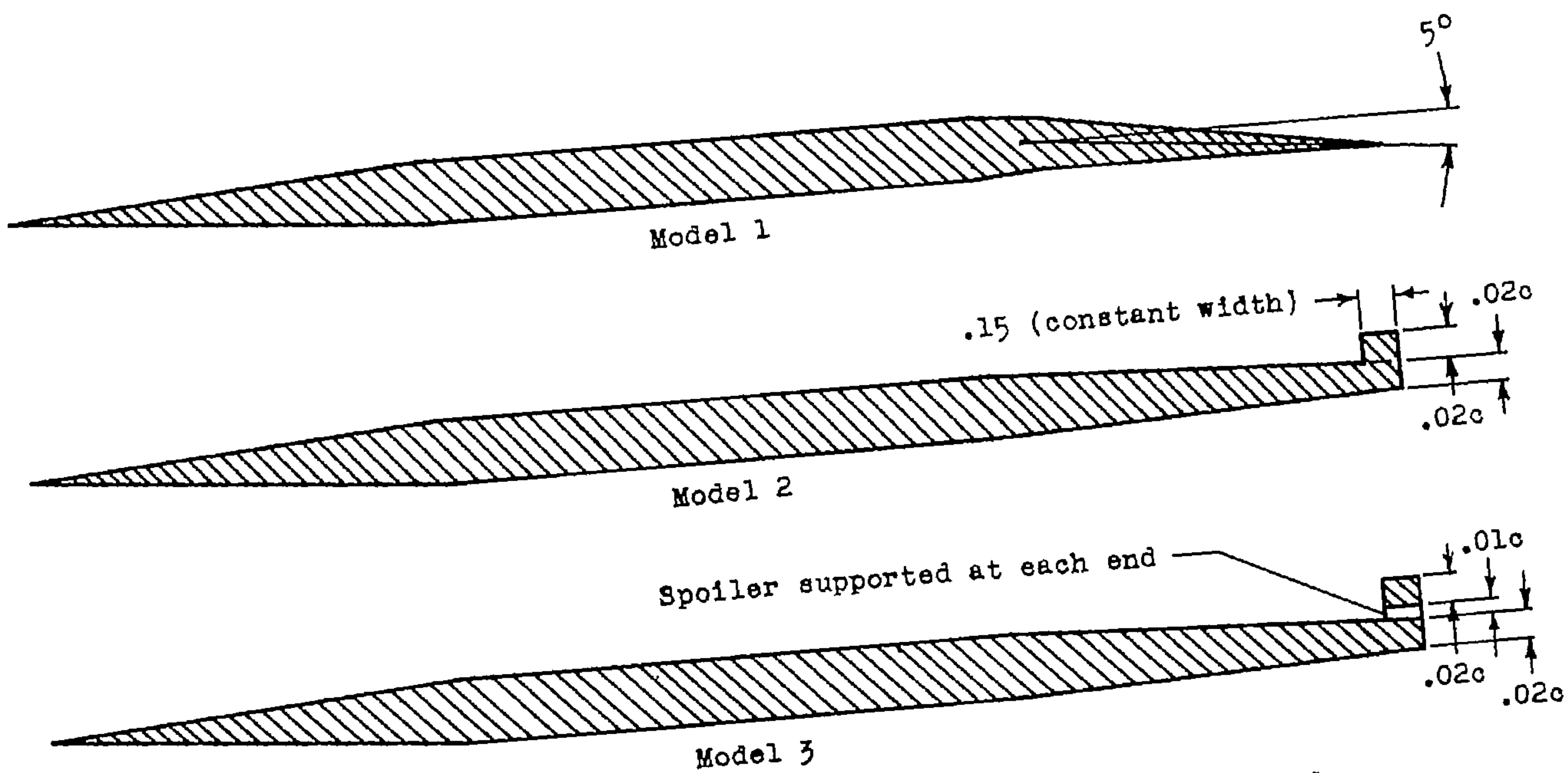
(b) Close-up of trailing-edge spoiler on model 2.

Figure 1.- Concluded.



(a) Sketch of typical model.

Figure 2.- Geometric details and dimensions of test models. All dimensions are in inches.



(b) Enlarged wing sections in portion of wing over which controls extend.

Figure 2.- Concluded.

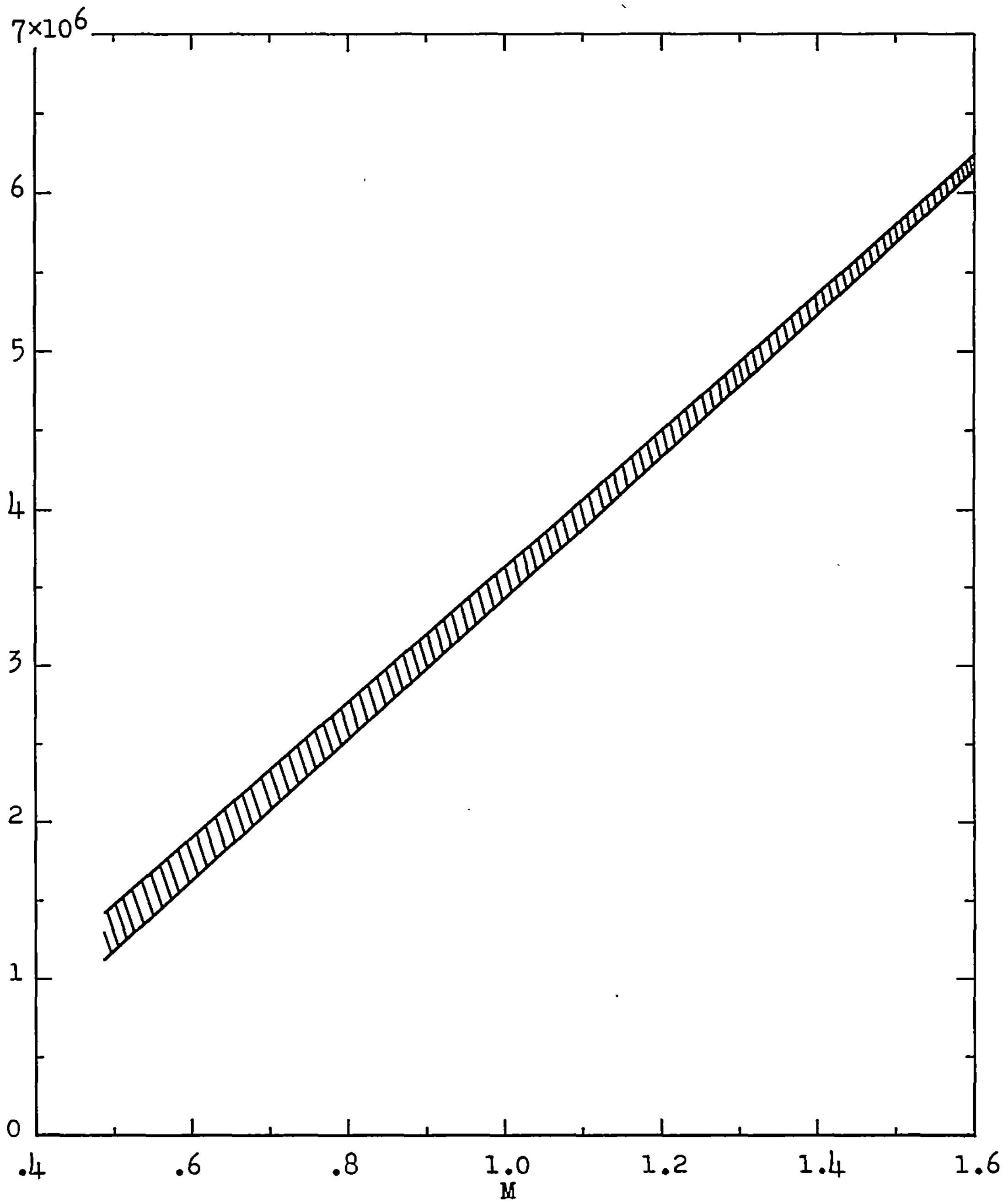


Figure 3.- Variation of test Reynolds numbers with Mach number. Reynolds numbers based on mean exposed wing chord, 0.626 foot.

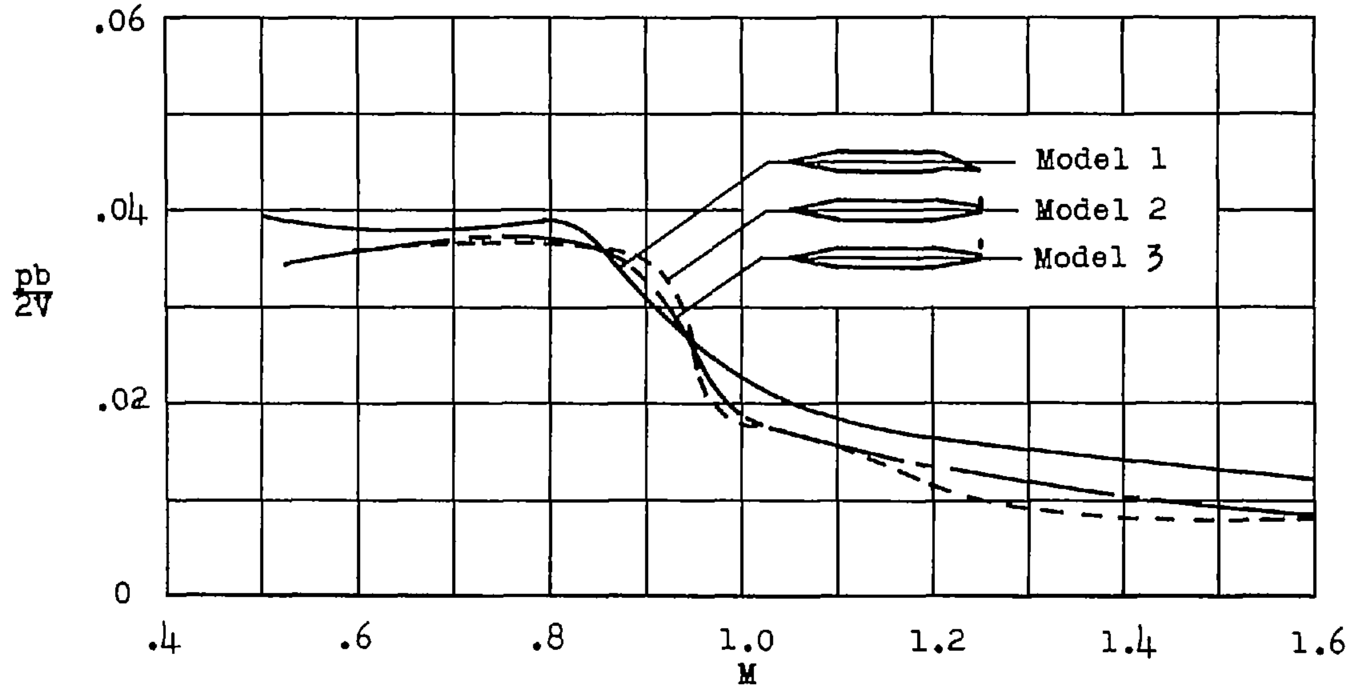


Figure 4.- Variation of rolling effectiveness parameter pb/2V with Mach number at model flight altitudes.

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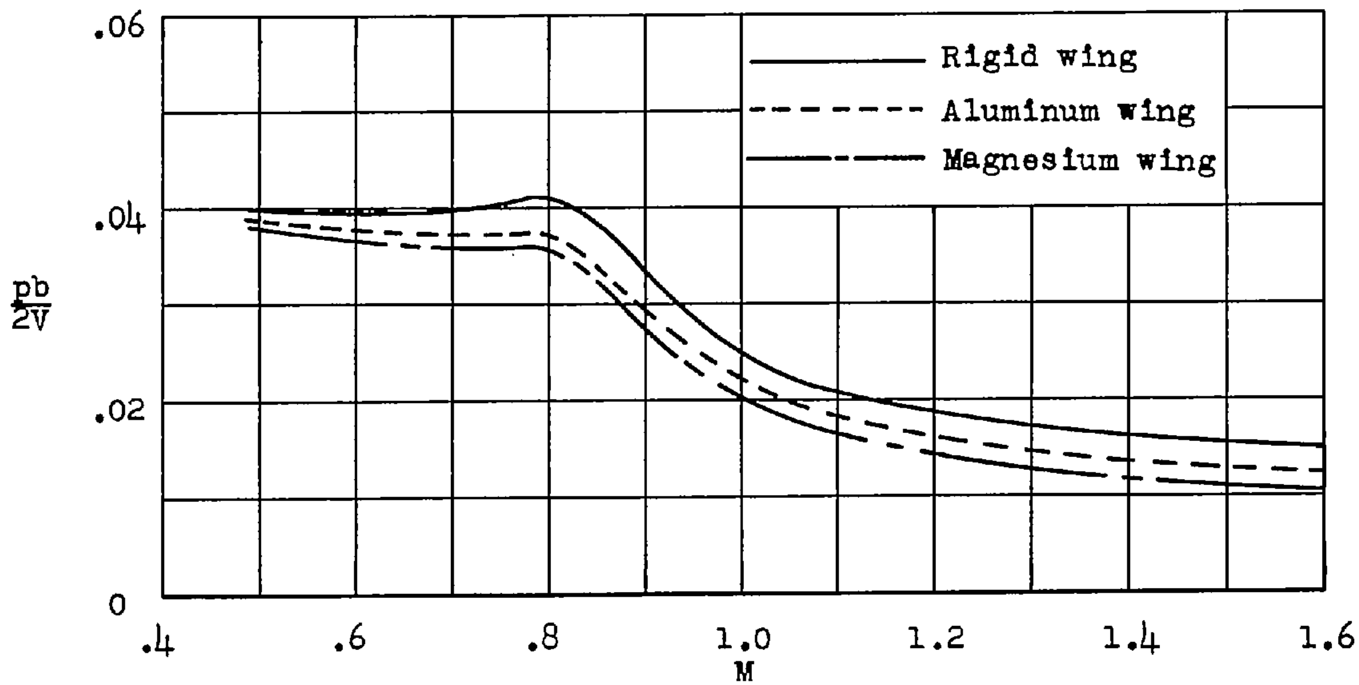

Figure 5.- Effects of aeroelasticity on aileron rolling effectiveness at sea level obtained from theoretical correction to experimental data.

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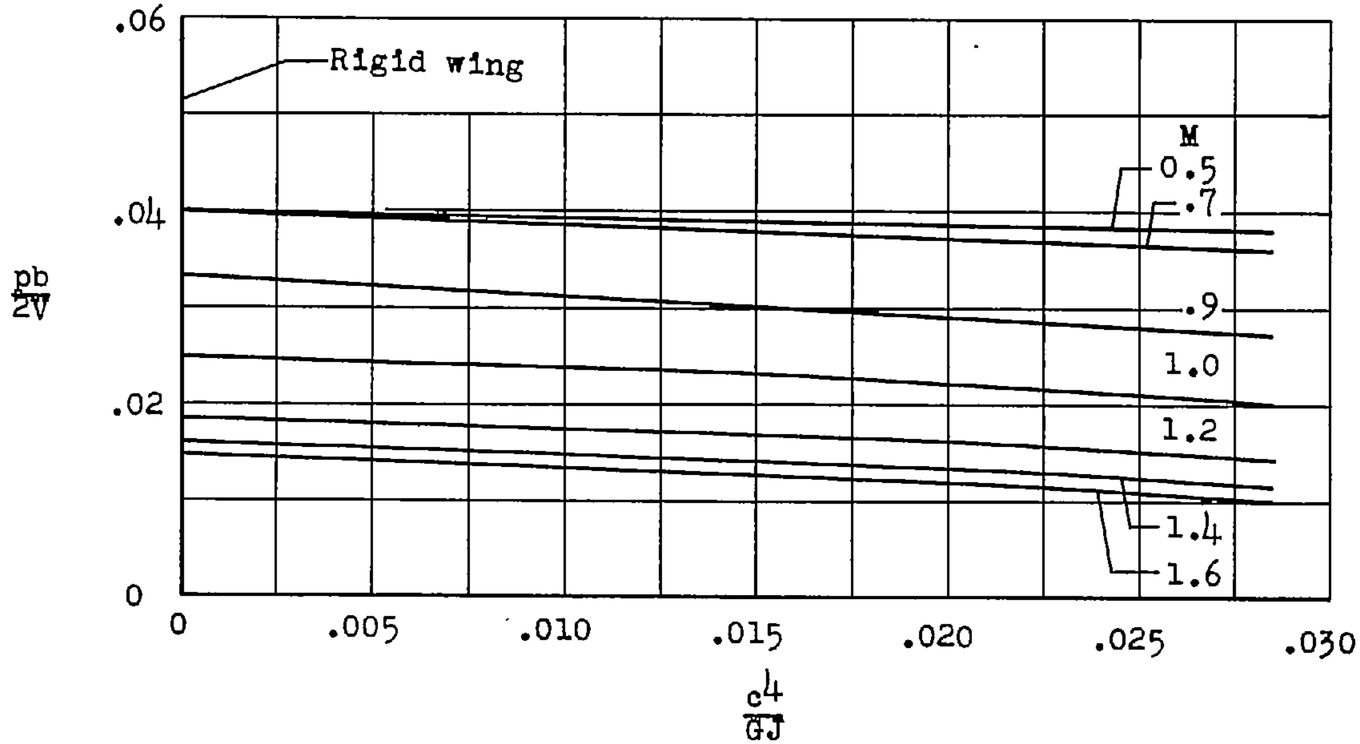

Figure 6.- Variation of aileron rolling effectiveness with structural-stiffness parameter c^4/GJ obtained from theoretical correction to experimental data.

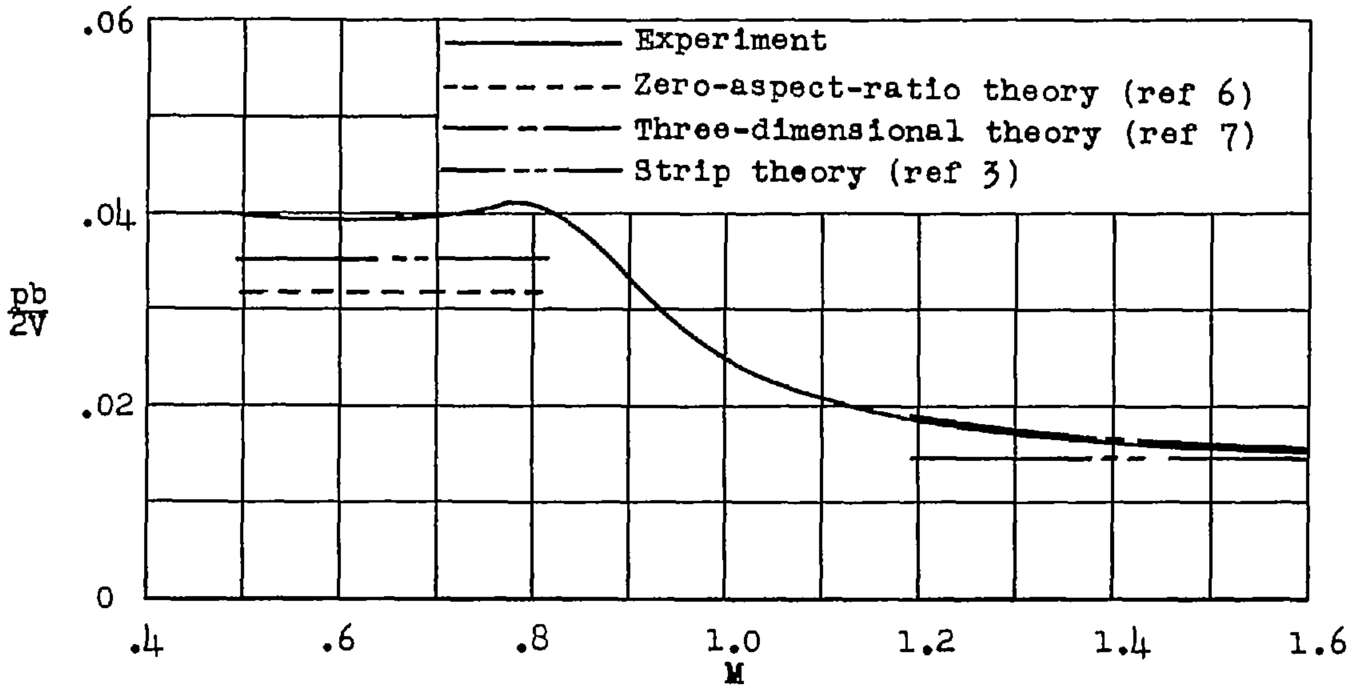

Figure 7.- Comparison of experimental and theoretical rigid-wing aileron rolling effectiveness.

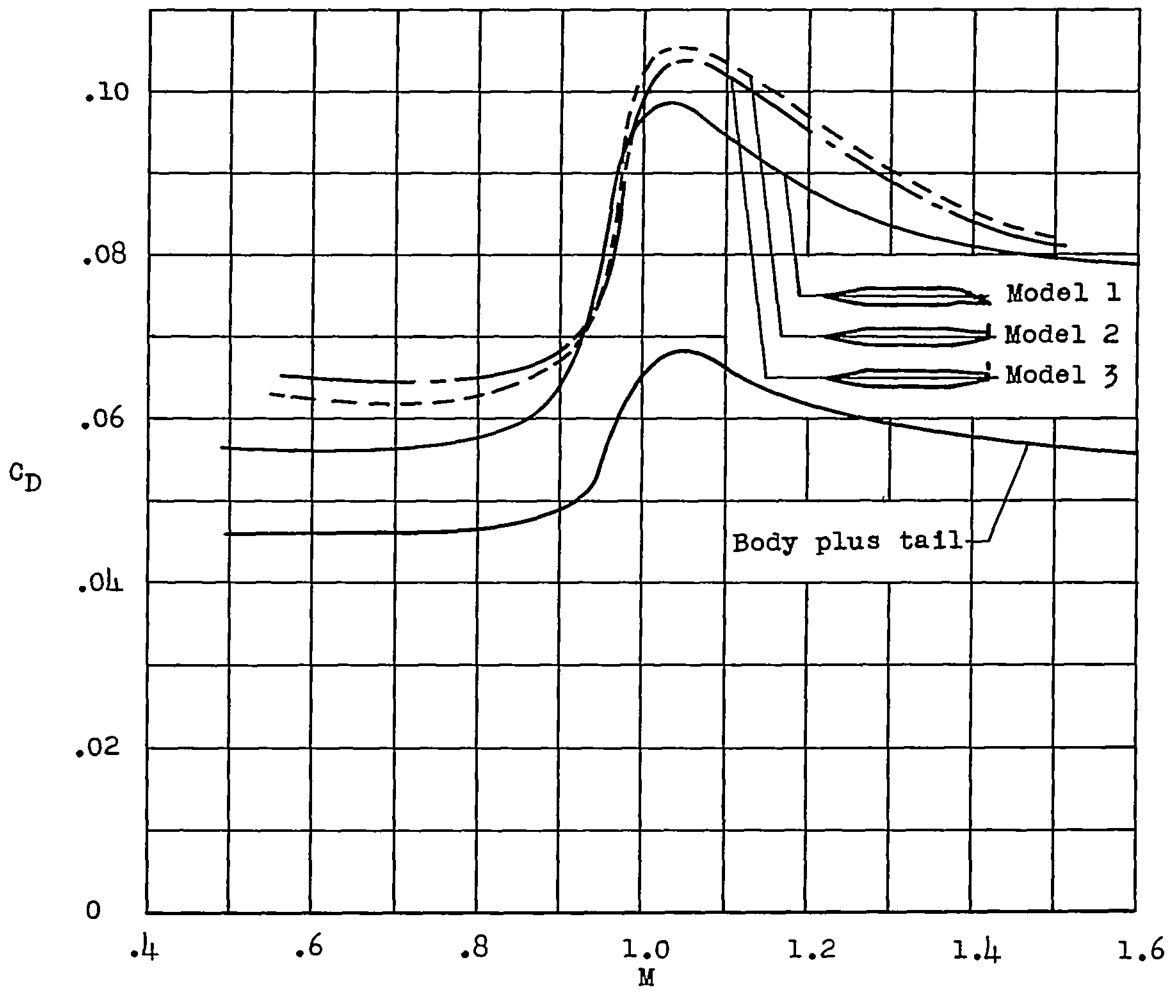

Figure 8.- Variation of drag coefficient C_D with Mach number.